

## CLAIMS

1. A niobium powder for a capacitor, comprising a niobium layer and a mixed layer of silicon nitride and niobium, the mixed layer being present in the vicinity of the powder particle surface.

2. The niobium powder for a capacitor as claimed in claim 1, wherein the thickness of the mixed layer is from 8 to 2,000 nm.

3. The niobium powder for a capacitor as claimed in claim 1, wherein the silicon nitride content is from 50 to 500,000 mass ppm.

4. The niobium powder for a capacitor as claimed in claim 1, wherein the silicon nitride is a compound represented by  $\text{Si}_\alpha\text{N}_\beta$ , wherein  $\alpha$  and  $\beta$  each represents a positive integer.

5. The niobium powder for a capacitor as claimed in claim 4, wherein the silicon nitride is at least one member selected from  $\text{SiN}$ ,  $\text{Si}_2\text{N}_2$ ,  $\text{Si}_2\text{N}_3$  and  $\text{Si}_3\text{N}_4$ .

6. The niobium powder for a capacitor as claimed in claim 1, wherein the niobium in the niobium layer and the mixed layer is at least one member selected from pure niobium, a niobium compound, a niobium alloy and a hydride thereof.

7. The niobium powder for a capacitor as claimed in claim 6, wherein the niobium compound is at least one

member selected from niobium hydride, niobium nitride and niobium oxide.

8. The niobium powder for a capacitor as claimed  
5 in claim 1, wherein the average particle size is from 0.05 to 5  $\mu\text{m}$ .

9. The niobium powder for a capacitor as claimed  
in claim 1, wherein the specific surface area is from 0.5  
10 to 70  $\text{m}^2/\text{g}$ .

10. A method for producing a niobium powder for a capacitor, comprising a step of etching a niobium powder, a step of impregnating the etched pores with silicon nitride,  
15 and a step of closing the etched pores.

11. The production method of a niobium powder for a capacitor as claimed in claim 10, wherein the niobium powder is a primary powder having an average particle size  
20 of 0.05 to 5  $\mu\text{m}$ , or an aggregated or granulated powder thereof.

12. The production method of a niobium powder for a capacitor as claimed in claim 10, which comprises a step of  
25 doping at least one element selected from the group consisting of nitrogen, oxygen, phosphorus, sulfur, selenium and tellurium, after the etching step but before the impregnation step, after the impregnation step but before the closing step, or after the closing step.

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13. The production method of a niobium powder for a capacitor as claimed in claim 10, wherein the step of

closing etched pores is performed in the presence of niobium, a niobium compound, niobium alloy or hydride thereof having an average particle size of 1 to 200 nm.

5           14.    The production method of a niobium powder for a capacitor as claimed in claim 10, wherein the niobium powder is at least one member selected from niobium, a niobium compound, a niobium alloy and a hydride thereof.

10           15.    The production method of a niobium powder for a capacitor as claimed in claim 14, wherein the niobium compound is a niobium compound containing nitrogen and/or oxygen.

15           16.    The production method of a niobium powder for a capacitor as claimed in claim 10, wherein the etching agent for use in the etching step is an acid or an alkali.

20           17.    The production method of a niobium powder for a capacitor as claimed in claim 16, wherein the etching agent is an acid solution containing hydrofluoric acid or fluoroacetic acid.

25           18.    The production method of a niobium powder for a capacitor as claimed in claim 16, wherein the etching agent is an alkali solution having a pH of 10 or more.

30           19.    The production method of a niobium powder for a capacitor as claimed in claim 10, wherein the silicon nitride impregnated is a particle having an average particle size of 1 to 200 nm.

20. The production method of a niobium powder for a capacitor as claimed in claim 10, wherein ultrasonic irradiation is performed in the impregnation step.

5 21. A granulated niobium powder for a capacitor, obtained by granulating the niobium powder for a capacitor described in any one of claims 1 to 9 above.

10 22. A granulated niobium powder for a capacitor, comprising a niobium layer and a mixed layer of silicon nitride and niobium, the mixed layer being present in the vicinity of the outer surface and in the vicinity of the in-pore surface.

15 23. The granulated niobium powder for a capacitor as claimed in claim 22, wherein the thickness of the mixed layer is from 8 to 2,000 nm.

20 24. The granulated niobium powder for a capacitor as claimed in claim 22, wherein the silicon nitride content is from 50 to 500,000 mass ppm.

25 25. The granulated niobium powder for a capacitor as claimed in claim 21 or 22, wherein the average particle size is from 5 to 1,000  $\mu\text{m}$ .

26. The granulated niobium powder for a capacitor as claimed in claim 21 or 22, wherein the specific surface area is from 0.5 to 40  $\text{m}^2/\text{g}$ .

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27. The granulated niobium powder for a capacitor as claimed in claim 21 or 22, wherein one or more peak(s)

of the pore diameter distribution is present in the range of 0.01 to 500  $\mu\text{m}$ .

28. The granulated niobium powder for a capacitor  
5 as claimed in claim 25, wherein at least one peak of the pore diameter distribution is present in the range of 0.1 to 0.9  $\mu\text{m}$  and at least one peak is present in the range of 0.9 to 3  $\mu\text{m}$ .

10 29. A niobium sintered body for a capacitor, obtained by sintering the niobium powder for a capacitor claimed in any one of claims 1 to 9.

15 30. A niobium sintered body for a capacitor, obtained by sintering the granulated niobium powder for a capacitor claimed in any one of claims 21 to 28 above.

20 31. A niobium sintered body for a capacitor, comprising a niobium layer and a mixed layer of silicon nitride and niobium, the mixed layer being present in the vicinity of the outer surface of the sintered body and in the vicinity of the in-pore surface.

25 32. The niobium sintered body for a capacitor as claimed in claim 31, wherein the thickness of the mixed layer is from 8 to 2,000 nm.

30 33. The niobium sintered body for a capacitor as claimed in claim 31, wherein the silicon nitride content is from 50 to 500,000 mass ppm.

34. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31 above, wherein the porosity is 55 vol% or more.

5 35. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31, wherein the specific surface area is  $0.006 \text{ m}^2/\text{mm}^3$  or more.

10 36. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31, wherein the specific surface area is from  $0.005 \text{ m}^2/\text{mm}^3$  to  $0.06 \text{ m}^2/\text{mm}^3$ .

15 37. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31, wherein one or more peak of the pore diameter distribution is present in the range of 0.01 to 100  $\mu\text{m}$ .

20 38. The niobium sintered body for a capacitor as claimed in claim 37, wherein at least one peak of the pore diameter distribution is present in the range of less than 1.0  $\mu\text{m}$  and at least one peak is present in the range of 1.0  $\mu\text{m}$  or more.

25 39. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31 above, wherein the volume of pores having a diameter of 1  $\mu\text{m}$  or more is 13 vol% or more of the entire pore volume.

30 40. The niobium sintered body for a capacitor as claimed in any one of claims 29 to 31 above, wherein the capacitance is from 40,000 to 400,000  $\mu\text{FV/g}$ .

41. A capacitor comprising the niobium sintered body for a capacitor claimed in any one of claims 29 to 40 above as one electrode, a counter electrode and a dielectric material intervening between the electrodes.

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42. The capacitor as claimed in claim 41, wherein the dielectric material mainly comprises niobium oxide containing silicon nitride.

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43. A capacitor comprising a sintered body for a capacitor as one electrode, a counter electrode and a dielectric material intervening between the electrodes, wherein the dielectric material mainly comprises niobium oxide containing silicon nitride.

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44. The capacitor as claimed in claim 41 or 43, wherein the material for the counter electrode is at least one material selected from the group consisting of an electrolytic solution, an organic semiconductor and an inorganic semiconductor.

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45. The capacitor as claimed in claim 44, wherein the organic semiconductor is at least one member selected from the group consisting of an organic semiconductor comprising benzopyrroline tetramer and chloranil, an organic semiconductor mainly comprising tetrathiotetracene, an organic semiconductor mainly comprising tetracyanoquinodimethane, and an electrically conducting polymer.

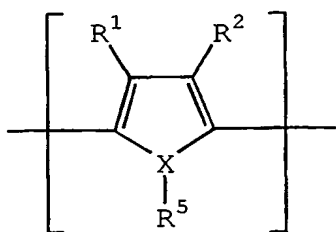
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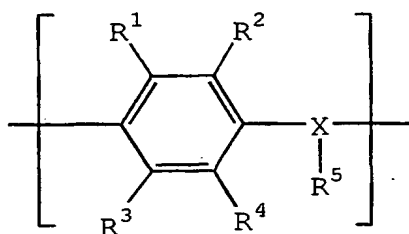
46. The capacitor as claimed in claim 45, wherein the electrically conducting polymer is at least one member selected from polypyrrole, polythiophene, polyaniline and

substitution derivatives thereof.

47. The capacitor as claimed in claim 45, wherein the electrically conducting polymer is an electrically conducting polymer obtained by doping a dopant into a polymer containing a repeating unit represented by the following formula (1) or (2):



(1)



(2)

wherein R<sup>1</sup> to R<sup>4</sup> each independently represents a monovalent group selected from a hydrogen atom, a linear or branched, saturated or unsaturated alkyl, alkoxy or alkyl ester group having from 1 to 10 carbon atoms, a halogen atom, a nitro group, a cyano group, a primary, secondary or tertiary amino group, a CF<sub>3</sub> group, a phenyl group and a substituted phenyl group,

the hydrocarbon chains of R<sup>1</sup> and R<sup>2</sup>, or R<sup>3</sup> and R<sup>4</sup> may combine with each other at an arbitrary position to form a divalent group for forming at least one 3-, 4-, 5-, 6- or 7-membered saturated or unsaturated hydrocarbon cyclic structure together with the carbon atoms to which these substituent groups are bonded,

the cyclic combined chain may contain, at an arbitrary position thereof, a carbonyl bond, an ether bond, an ester bond, an amido bond, a sulfido bond, a sulfinyl bond, a sulfonyl bond or an imino bond,

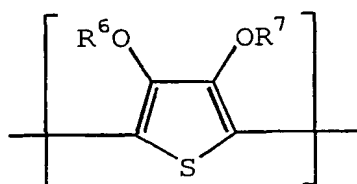
X represents an oxygen atom, a sulfur atom or a



nitrogen atom, and  $R^5$  is present only when X is a nitrogen atom, and represents a hydrogen atom or a linear or branched, saturated or unsaturated alkyl group having from 1 to 10 carbon atoms.

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48. The capacitor as claimed in claim 47, wherein the electrically conducting polymer is an electrically conducting polymer obtained by doping a dopant into a polymer containing a repeating unit represented by the following formula (3):



(3)

wherein  $R^6$  and  $R^7$  each independently represents a hydrogen atom, a linear or branched, saturated or unsaturated alkyl group having from 1 to 6 carbon atoms, or a substituent for forming at least one 5-, 6- or 7-membered saturated hydrocarbon cyclic structure containing two oxygen atoms when the alkyl groups are combined with each other at an arbitrary position, and

the cyclic structure includes a structure having a vinylene bond which may be substituted, and a phenylene structure which may be substituted.

49. The capacitor as claimed in claim 48, wherein the electrically conducting polymer is an electrically conducting polymer obtained by doping a dopant into poly(3,4-ethylenedioxythiophene).

50. The capacitor as claimed in claim 41 or 43, wherein the material for the counter electrode has a layered structure at least in a partial portion.

5 51. The capacitor as claimed in claim 41 or 43, wherein the material for the counter electrode contains an organosulfonate anion as a dopant.

52. An electronic circuit using the capacitor  
10 claimed in any one of claims 41 to 51.

53. An electronic device using the capacitor claimed in any one of claims 41 to 51.